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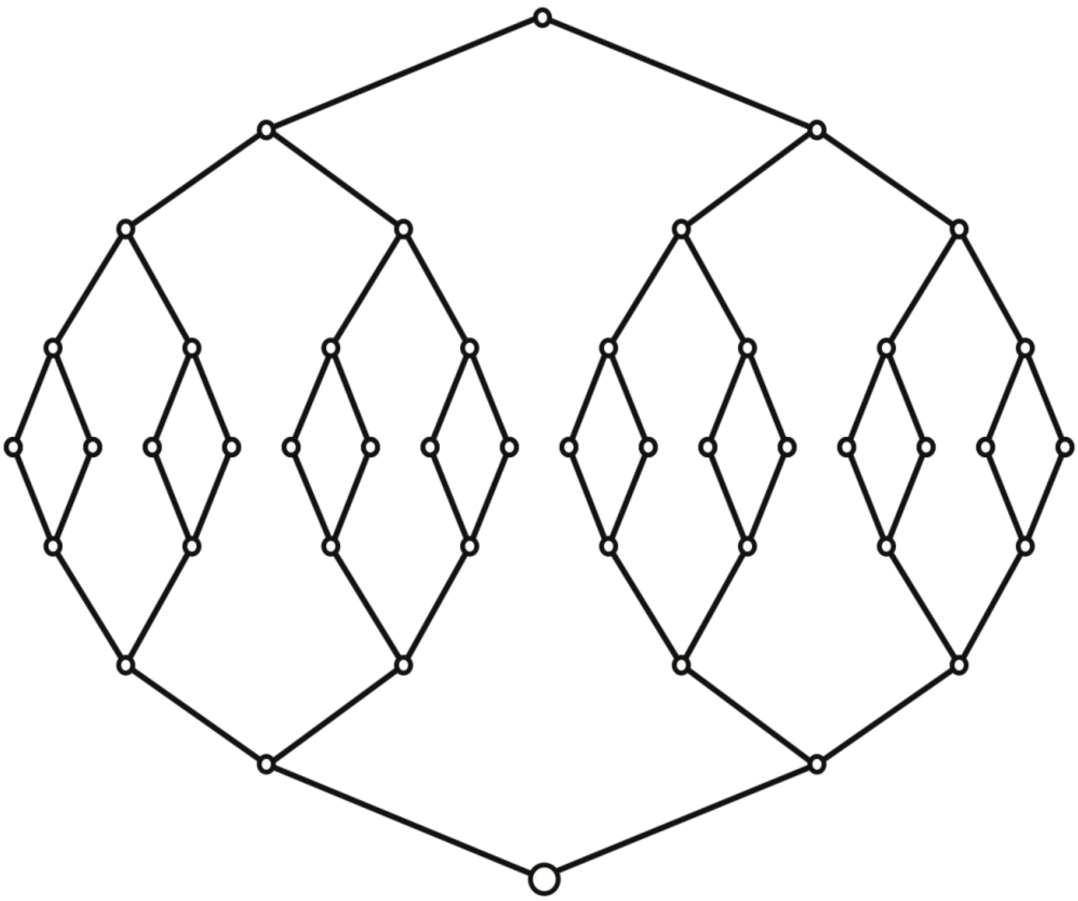

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Scaling relative asymmetry in space syntax analysis

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This paper reports on a study of space syntax measures and focuses on the standard deviation of the depth from an axial map. The first section of the paper is a partial review of the original study 'On node and axial maps: Distance measures and related topics' (Krüger, 1989). The following sections present new developments whereby a more robust statistical approach to work with integration is used, which not only considers the mean values given by Relative Asymmetry (RA), but also the corresponding standard deviation. In other words, the proposition is to work not only with a measure of centrality (1/RA), but also with a dispersion measure in order to obtain a more complete picture of the distribution of depth in an axial map. The result of this study on space syntax measures takes into account the standard deviation of the depth from an axial map, proposing a new measure of Scaled Relative Asymmetry of axial line *i* (SRA_i), which suggests powerful correlations with natural movement.

Keywords:
Space syntax measures, axial map analysis, depth standard deviation.

1. Introduction

At the social level, space affects human behaviour and has the potential to induce our actions and influence their usages. The space syntax theory supports the idea that space and its configuration have a great influence on the socialisation processes that occur in those occupied and used spaces.

This theory was first developed at University College London in the Unit of Architectural Studies (Hillier and Hanson, 1984) and has a particular way of representing space in order to systemise information for the comprehension of different spatial characteristics.

The space syntax studies developed at University College London have led to the natural movement theory, concluding that through the combination of different information about the spatial patterns and observation studies, pedestrian movement tends to be associated with the morphology of the space. In other words, space syntax states that some places are better integrated than others, usually indicated by a higher flow of people. This type of relationship does not depend only on the individual spaces, but on the configuration of those spaces as a whole (Hillier et al., 1993).

The theory of space syntax aims to analyse space and its configuration, focusing on their implications for social relations and pedestrian movement. This method allows the study of different systems of spatial relations, which characterise different spaces (Hillier and Hanson, 1984; 1987).

Spatial systems are graphically represented by their axial map – the bi-dimensional representation of the main lines that connect the entire spatial system, in which every line stands for a possibility of flow between two spaces without physical or visual barriers.

Interpretation of space syntax measures in these maps is sensitive to the scale of the maps, since their values are dependent on the size of the space under study. This issue is particularly relevant when we compare measures across different urban or buildings spaces, and it is therefore necessary to place variables on a common scale obtained by standardisation methods. This standardised measure, introduced by Hillier and Hanson (1984) for expressing integration, is called Real Relative Asymmetry (RRA).

Krüger (1989) also indicates a standardisation procedure for RA – Real Relative Asymmetry (RRA) – that is presented in the next section of this paper. Normalisation is obtained by comparing a centrality measure of a node of a graph with *n* nodes, with the centrality measure we would get if that node were the root of a standardised graph in a diamond shape with the same number of nodes.

These procedures have been shown to be robust in practice, but nevertheless have been a matter for considerable discussion. Reflecting on the problem of desirable integration measures that are independent of the size of the axial map of urban or building space, Teklenberg, Timmermans and Wagenberg (1993) propose a new measure and compare it with the existing measures of RRA, suggesting a logarithmic transformation of the total depth of a system. However, this method cannot produce values for all axial maps if there is a space where total depth is less than or equal to the total number of spaces in the system. These authors suggest an integration score primarily for urban plans or very large buildings and, in the other cases, the distribution of integration should be calculated using Hillier and Hanson's (1984) method.

As a matter of fact, the Teklenberg, Timmermans and Wagenberg (1993) approach relies on the standardisation of mean integration but does not take into account the standard deviation of depths values. Also Conroy-Dalton and Dalton's (2007) work assumes a decay function for the distribution of depth values, making an hypothesis on the form that distribution, which is not necessary if we have mean and standard deviation of d-values to compare two or more distributions.

Indeed, mean and standard deviation values are essential for understanding the distribution of space syntax values in axial maps because, regardless of the mean, it makes a great deal of difference whether the distribution is spread out over a broad range or clustered closely around the mean.

The work presented here is based on the study 'On node and axial maps: Distance measures and related topics' (Krüger, 1989), and also on new developments which consider a more robust statistical approach to work with integration that not only takes into account the mean values given by RA, but also the corresponding standard deviation. Consequently the paper has two parts, the first being a review of the original study (*ibid.*) which presents some basic space syntax measures and the derivation of the RA measure, based on mean depths from an axial line to all others. In the second part of the paper, a new measure called Scaled Relative Asymmetry (SRA) is developed which aims to take into account not just mean depths, but also a measure of their variation. The proposition is therefore to not only take into account a measure of centrality (1/RA), but also a dispersion measure in order to obtain a more complete picture of the distribution of depths in an axial map. Subsequently it is suggested that SRA performs better then RA, since it takes into account the 'form of depths' distribution' and not just its mean.

2. General Properties of Axial Maps

Axial maps usually represent different properties of urban form and consist of the fewest longest straight lines that cover all urban public spaces, i.e. lines that pass through all urban public spaces configured as unified places. These axial lines have properties of visibility, referring to how far one can see; and permeability, relating to how far one can go.

However, a more precise definition is needed if we want to achieve an accurate description of these maps in order to explore their properties.

An axial map (AM) consists of a finite non empty set L = L(A) of *k* lines together with a prescribed set X of *m* unordered pairs of lines of L.

Each pair $x = \{u, v\}$ of lines in X is called a connection (or point) and *x* is said to join *u* and *v*. We write $x = uv$ and say that u and v are adjacent axial lines; point x and line u are incidental to each other, as are x and v.

An axial map with k lines and m connections is called a (m, k) map, the (0, 1) map being a trivial case represented just by an axial line.

For the (8, 6) axial map represented in Figure 1, the set of lines is defined as being given by L = {1, 2, 3, 4, 5, 6} and the set of connections as being given by X_1 = {1, 2}, X_2 = {2, 3}, X_3 = {3, 4}, X_4 = {3, 6}, X_5 = {3, 5}, X_6 = {4, 6}, X_7 = {4, 5} and X_8 = {1, 6}.

A graph G of a (m, k) axial map consists of a finite non-empty set V = V(G) of k vertices together with a prescribed set X of m unordered pairs of distinct vertices of V. Each vertex in G represents a line of the (m, k) axial map and each pair $y = \{r, s\}$ of vertices in G represents a connection of the axial map. Each pair $y = \{r, s\}$ of vertices in G is an arc of G and y is said to join u and v. A graph G with k vertices and m arcs is called a (k, m) graph.

The (6, 8) graph represented in Figure 1 is described by the set of vertices V = {1, 2, 3, 4, 5, 6} and by the sets of arcs Y_1 = {1, 2}, Y_2 = {2, 3}, Y_3 = {3, 4}, Y_4 = {3, 6}, Y_5 = {3, 5}, Y_6 = {4, 6}, Y_7 = {4, 5} and Y_8 = {1, 6}.

It should be noted that the application AM (m, k) $\rightarrow$ GM (k, m) is non isomorphic; i.e. while an axial map corresponds to just one graph, to the same graph there correspond many axial maps. In short, an axial map AM (m, k) corresponds to one graph G (k, m), but the converse is not true.

For an axial map, the maximum number of connections for a given set of k lines is given by (C_2^k)

$$m_{\max} = \frac{k(k-1)}{2} \qquad (1)$$

which is identical to the maximum number of lines that a graph G with k points can have (Harary, 1971, p.16). In graph theory terminology, G is called a complete graph since every pair of its k points is adjacent. In a similar way we can say that an (m_{max}, k) axial map is a complete axial map.

A graph is said to be connected if every pair of points can be joined by a path; i.e. by an alternating sequence of points and lines, in which all points and lines are distinct and where each line is incidental

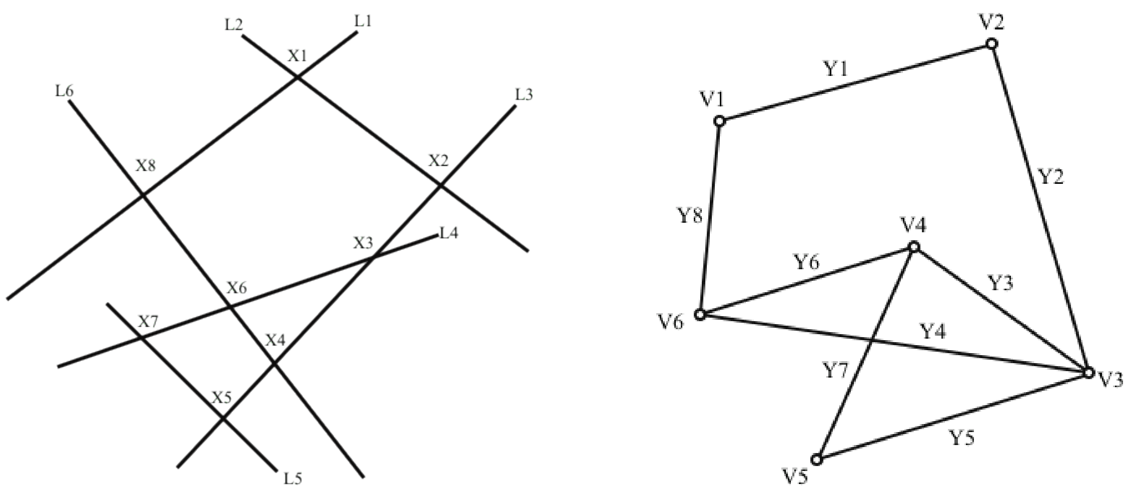


Figure 1:

An example of an (8, 6) axial map and its correspondent (6, 8) graph.

to the two points immediately preceding and following it. A path is considered closed if its first point is identical to the last one. For a minimally connected axial map, the corresponding graph G is called a tree; i.e. a connected graph with minimum number of lines, without closed paths or cycles. In a tree with k vertices there must be k-1 lines; thus a lower limit (m_{min}) for the number of connections in the axial map is given by k-1.

3. Definition of Distance Measures on Axial Maps

Several distance measures have been proposed in the literature to analyse the performance of the graph representation of the axial map.

In general, we can speak of the distance d_{ij} between two points i and j in graph G as being the length of the shortest path joining them, if any; otherwise $d_{ij} = \infty$. In a connected graph, distance presents metric properties, i.e. for all points i, j and k (Harary, 1971, p.14), the following set of axioms holds:

1. $d_{ij} \geq 0$, with $d_{ij} = 0$ if and only if $i = j$,
2. $d_{ij} = d_{ji}$,
3. $d_{ij} + d_{jk} \geq d_{ik}$.

In axial maps the distance between line i and j is, generally measured by the number of depth steps, i.e. the number of axial lines located on the shortest path joining them.

Mean depth of line i in an axial map is defined by

$$MD_i = \sum_{j=1}^{k} \frac{d_{ij}}{(k-1)} \qquad (2)$$

where k represents the number of lines in the axial map or the number of points in its graph representation.

Mean depth measures the extent to which a given line i is segregated from the remaining lines of each map. In that sense mean depth can be called a global property of a specific axial line.

In order to standardise the variation of mean depth between zero and one, Hillier and Hanson (1984, p.108) proposed the following measure, known as the Relative Asymmetry (RA) of a line or node i

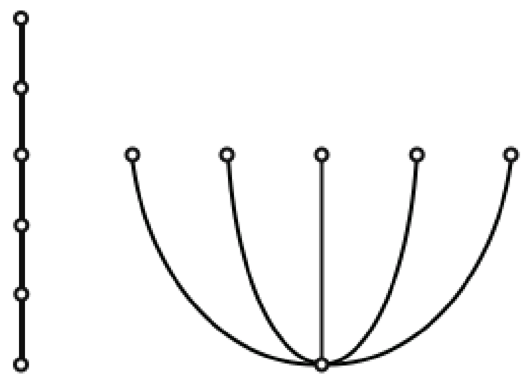
$$RA_i = \frac{2(MD_i - 1)}{(k-2)} \qquad (3)$$

where the variables have the usual meaning.

To obtain expression (3) we need to know the maximum and minimum values that an axial line can have in terms of mean depth.

The minimum value is given when node i in a graph G is at minimum depth from all other ones, i.e. when it is at depth 1 from all other nodes. In that case the minimum mean depth is 1, i.e. $MD_{min} = 1$. In graph theory terminology this corresponds to the centre of a star.

The maximum value for MD_i is given when node i is the end point of a chain, i.e. of a tree with two points incidental to one line and the remaining (k-2) points incidental to two lines.



a) RA_{max} b) RA_{min}

Figure 2:

a) Chain having end point with maximum RA.
b) Star having centre with minimum RA.

The total depth of an end point i in a chain is given by the following expression $\sum_{j=1}^{k} d_{ij} = \sum_{m=1}^{k-1} m$, i.e. is identical to the summation of natural numbers, from m = 1, which corresponds to the node j at depth 1 from i, up to k-1, which corresponds to the deepest node j from i.

The summation of the series of natural numbers, from 1 up to k-1, is given by $m_{\max} = \frac{k(k-1)}{2}$. Therefore, the mean depth of an end node i in a chain is given by $MD_{\max} = \frac{k}{2}$.

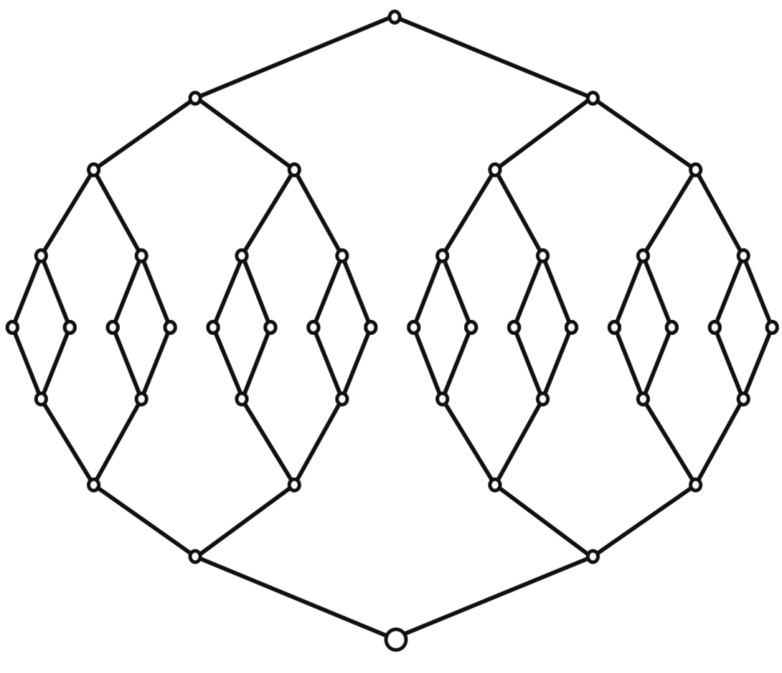
The expression of RA_i, defined to vary between 0 and 1, is given in its standardised form as

$$RA_i = \frac{MD_i - MD_{\min}}{MD_{\max} - MD_{\min}} \qquad (4)$$

Substituting the values of MD_{min} and MD_{max} in expression (4), we obtain expression (3) which gives the value of the RA of point i. Values close to 1 represent segregated points in relationship to the whole graph, while values close to 0 represent points integrated in the system.

However, as it stands, expression (3) does not allow us to directly compare the values of RA for points located in maps of different sizes. In fact, as k increases, the mean depth decreases, *ceteris paribus*, in proportionate terms. This means that RA measures also decrease in proportionate terms when the number of axial lines increases; it is therefore impossible to compare systems of different sizes.

The usual approach is to compare RA values for each point with RA values of a root of a diamond shape. The reason for adopting this procedure rests on the assumption that, in both cases, the depths are approximately normally distributed.



Level	Nº Points	Depth
- 9	2^0	8
- 8	2^1	7
- 7	2^2	6
- 6	2^3	5
- 5	2^4	4
- 4	2^3	3
- 3	2^2	2
- 2	2^1	1
- 1	2^0	0

Figure 3:

D_{46} - Diamond Shape with 46 points and 9 levels of depth.

A diamond shape, as a graph, is a special form of justified graph. A justified graph is one in which a point, called the root, 'is put at the base and then all points of depth 1 are aligned horizontally above it, all points at depth 2 from that point above those at depth 1, and so on until all levels of depth from that point are accounted for' (Hillier and Hanson, 1984, p.106). In a diamond shape there are *k* points at mean depth level, *k*/2 at one level above and below, *k*/4 at two levels above and below, and so on until there is one point at the shallowest (the root) and deepest levels (*ibid.*, p.111-112).

For an axial map with *k* lines, the general procedure (see *ibid.*, p.112-113) has been to estimate the D_k, i.e. the RA of the root of a diamond shape with *k* points, and to divide the RA value found for a specific line of the axial map by the value obtained for D_k. This new value has been called Real Relative Asymmetry (RRA) in the literature (see *ibid.*, p.112) and varies above and below 1. Values well below 1, such as those lower than 0.6, indicate strongly integrated lines in the axial map, whilst values above 1 indicate more segregated lines.

4. Scaling Relative Asymmetry

In order to compare the performance of different procedures to standardise the RA of an axial map, we need to obtain an expression for the RA of the diamond root as a function of the number of its points.

In a diamond shape with *k* nodes, the total depth from its root TD_k, in relationship with all other points, is given by the following expression

$$TD_k = \sum_{q=0}^{d/2} q(2^q) + \sum_{q=0}^{d/2-1} (d-q)(2^q) \qquad (5)$$

where *d* represents the maximum depth from the root and *q* the depth, also from the root, of the points located on each level.

The first term $S_1 = \sum_{q=0}^{d/2} q(2^q)$ on the right hand side of equation (5) represents the total depth of the root in relationship to those points located from depth 0 to depth *d/2*. The second term $S_2 = \sum_{q=0}^{d/2-1} (d-q)(2^q)$ represents the same in relationship to those points situated at depth (*d/2+1*), up to maximum depth *d* from the root.

As, in general, $\sum_{q=0}^{n} q(2^q) = \left[(n-1)(2^{(n+1)}) + 2\right]$ (see Graham et al., 1989, p. 33), then the first term in the right hand side of expression (5) becomes

$$S_1 = \left[(d/2 - 1)(2^{(d/2+1)}) + 2\right] .$$

For the second term, after expansion, it becomes $S_2 = \sum_{q=0}^{d/2-1} d(2^q) + \sum_{q=0}^{d/2-1} q(2^q)$.

Substitution of these expanded terms S_1 and S_2 in (5) gives the following result

$$TD_k = S_1 + S_2 = \sum_{q=0}^{d/2} q(2^q) + \sum_{q=0}^{d/2-1} q(2^q) - \sum_{q=0}^{d/2-1} d(2^q)$$

(6)

The first two terms in the right hand side of expression (6) partially cancel out, giving the following result

$$TD_k = (d/2)(2^{d/2}) + \sum_{q=0}^{d/2-1} d(2^q) \qquad (7)$$

But, in general, as $\sum_{k=0}^{n} ax^k = \frac{(a - ax^{n+1})}{(1-x)}$ then, developing the second term in the right hand side of expression (7), we obtain

$$TD_k = (3/2)(d2^{d/2}) - d \qquad (8)$$

Expression (8) gives the total depth of a root of a diamond shape as a function of *d*, i.e. as a function of the maximum depth from that root.

As in a diamond shape (see Figure 3) *d/2=n*, where *n* in expression 2^n represents the depth of the diameter of a diamond, i.e. of the diamond's level with the greatest number of points, and 2^n stands for the number of points at that level, then if we substitute this result in (8) we obtain, after algebraic manipulation, for the total depth of a diamond

$$TD_k = 2n(3 \cdot 2^{(n-1)} - 1) \qquad (9)$$

Expression (9) gives the total depth of a diamond root as a function of its diameter depth.

The total number *k* of points in a diamond shape can be given as a function of its diameter depth, i.e. as a function of *n* by the following expression

$$k = 2^n + 2\sum_{i=0}^{n-1} 2^i$$

where the first expression on the right hand side represents the number of points at diameter level and the second one the number of points at all other levels.

As, in general, $\sum_{i=0}^{n} 2^i = \frac{(1-2^{n+1})}{(1-2)}$ then, after algebraic manipulation, the last equation for *k* could be transformed, by substitution, into

$$k = 3 \cdot 2^n - 2 \qquad (10)$$

If we substitute (10) in (9) we obtain an expression for the root total depth as a function of the number of diamond points (*k*) as well as a function of its diameter level (*n*), i.e. simply as

$$TD_k = k \cdot n \qquad (11)$$

Then the mean depth of a diamond root can now be given by

$$MD_k = (k \cdot n)/(k-1) \qquad (12)$$

If we substitute expression (12) in (3) we obtain the RA of a root of a diamond (D_k) as a function of the number of points *k* and the depth of its diameter *n*, i.e. by

$$D_k = \frac{2\left[k(n-1)+1\right]}{(k-1)(k-2)} \qquad (13).$$

However, from expression (10) we can estimate *n* as a function of *k*, which is given by

$$n = \lg_2\left(\frac{k+2}{3}\right) \qquad (14).$$

If we substitute the value of *n*, given by expression (14), in (13) we finally obtain the RA of a diamond root simply as a function of the number of its *k* points, i.e. as

$$D_k = \frac{2\left[(k(\lg_2(\frac{k+2}{3})-1)+1)\right]}{(k-1)(k-2)} \qquad (15).$$

The usual procedure in space syntax analysis is to standardise the RA by the values given by D_k, regardless of the form of depths distribution in axial maps.

If we want to compare axial maps of different sizes then we should have the same *yardstick* - not just in terms of their mean depths, but also concerning the dispersion of their values. In short, we should account for the entire distribution of depths on maps to be compared, not just their mean depths, as happens in the estimation of D_k which is only dependent on the value obtained for MD_k.

Therefore, we now need to obtain the standard deviation of depth values from a root of a diamond shape in order to convert RA values to a common scale and be able to compare axial maps of different sizes.

The following identity provides a basis for estimating the standard deviation of variable *x* on an interval scale distribution:

$$\sqrt{\left(\frac{\sum_{i=1}^{k}(x_i-\bar{x})^2}{k-1}\right)} = \sqrt{\left(\frac{\sum_{i=1}^{k}x_i^{\ 2}}{k-1}+(k-2)\left(MD_k\right)^2\right)} \quad (16)$$

where k represents the number of observations, the mean of the distribution and MD_k, as usual, the mean depth of a diamond root.

In order to estimate the standard deviation of depths on a diamond root (σD_k), we need to express in context, the expression $\sum_{i=1}^{k} x_i^{\ 2}$; i.e. we need to develop it in a similar fashion as we did for the total depth from its root (TD_k) given by expression (5).

In other words, we need to estimate the following expression,

$$\sum_{i=1}^{k} x_i^{\ 2} = \sum_{q=0}^{d/2} q^2(2^q) + \sum_{q=0}^{d/2-1}(d-q)^2(2^q) \quad (17)$$

where the variables have the usual meaning.

As the diameter's depth of a diamond shape equals half of the maximum depth from the root ($n = d/2$), then the right hand side of equation (13) could be transformed, by substitution, into

$$\sum_{q=0}^{n} q^2(2^q) + \sum_{q=0}^{n-1}(d-q)^2(2^q) \quad (18).$$

Developing and factoring both terms of expression (18), we obtain,

$$\sum_{i=1}^{k} x_i^{\ 2} = (3\cdot 2^n n^2 - 4n^2 - 8n + 3\cdot 2^{n+2} - 12) \quad (19).$$

If we substitute expressions (12) and (19) in (16), we find the standard deviation of depths on a diamond root (σD_k) given by

$$\sigma D_k = \sqrt{\frac{3\cdot 2^n n^2 - 4n^2 - 8n + 3\cdot 2^{n+2} - 12}{k-1} - (k-2)\left(\frac{kn}{k-1}\right)^2}$$

(20).

As $n = \lg_2((k+2)/3)$, we can express the σD_k just in function of its k elements, as we did it for D_k.

This gives a general procedure to standardise depth measures in order to convert them – with a certain mean and standard deviation – to a common scale that is only dependent on the number of their nodes.

That transformation can be done in one step by the following equation that converts values in one scale directly to comparable values in another scale by means of a linear transformation (Guilford and Fruchter, 1978, p.477)

$$STD_i = \left(\frac{\sigma D_i}{\sigma D_k}\right)TD_k - \left[\left(\frac{\sigma D_i}{\sigma D_k}\right)MD_k - MD_i\right] \quad (21)$$

where $MD_k = (k\cdot n)/(k-1)$;

$MD_i = \sum_{j=1}^{k} d_{ij}/(k-1)$, where d_{ij} stands for the shortest path between nodes i and j;

$TD_k = 2n(3.2^{n-1}-1)$;

σD_k is the standard deviation of depths for the root of a diamond shape with k elements;

σD_i is the standard deviation of depths for axial line i;

and STD_i represents the standardised total depth of axial line i.

Knowing σD_i and TD_i from a particular distribution of depth values in an axial map, we are now able to obtain the standardised value of its total depth STD_i and therefore the Scaled Relative Asymmetry of axial line i (SRA_i) given by its scaled mean depth (SMD_i) as

$$SRA_i = \frac{SMD_i - SMD_{\min}}{SMD_{\max} - SMD_{\min}} \quad (22),$$

where $SMD_i = STD_i/(k-1)$; SMD_{max} represents the standard mean depth of the end point of a chain with k nodes, and SMD_{min} the standard mean depth of the centre of a star with k nodes.

The expression (22) is equivalent to RA_i for non-standardised depth values that were defined to vary between 0 and 1 and given by expression (4).

We now need to estimate SMD_{min} and SMD_{max} in a similar fashion as we did for STD_i using an expression, in both cases, analogous to equation (21).

However, as the centre of a star has standard deviation equal zero, it means that the standardisation procedure given by the expression

$$SMD_{\min} = SMD_s = \frac{STD_s}{k-1}$$

$$STD_s = \left(\frac{\sigma D_s}{\sigma D_k}\right) TD_k - \left[\left(\frac{\sigma D_s}{\sigma D_k}\right) MD_k - MD_s\right] \quad (23),$$

where, STD_s stands for the standardised total depth of the centre of a star with k nodes, σD_s for standard deviation and MD_s for the mean depth of that node, and the other variables have the usual meaning, then it becomes $STD_s = MD_s$ (because $\sigma D_s = 0$).

Therefore, the standardised mean depth (SMD_s) of a star's centre with k nodes transforms into

$$SMD_s = \frac{1}{(k-1)} \quad (24),$$

On the other hand, to obtain SMD_{max} we need to calculate STD_c, i.e. the standardised total depth of the end point of a chain with k elements given by

$$SMD_{Max} = SMD_c = \frac{STD_c}{k-1}$$

$$STD_c = \left(\frac{\sigma D_c}{\sigma D_k}\right) TD_k - \left[\left(\frac{\sigma D_c}{\sigma D_k}\right) MD_k - MD_c\right] \quad (25),$$

where σD_k and σD_c are, respectively, the standard deviations of depths for the root of a diamond shape and of the end point of a chain with k elements; $MD_k = (k \cdot n)/(k-1)$; $MD_c = k/2$ stands for the mean depth and for the total depth from the root of a diamond shape with k nodes.

The only term that needs now to be estimated is σD_c. That can be done in a similar fashion as we did to obtain the standard deviation of variable x on an interval scale distribution

$$\sigma D_c = \sqrt{\left(\frac{\sum_{i=1}^{k}(i-\frac{k}{2})^2}{k-1}\right)} = \frac{k^3+2k}{12(k-1)} \quad (26).$$

Substituting the values of σD_c in equation (25), as well as all other variables already deduced, we obtain the standardised total depth (STD_c) of the end point of a chain with k nodes and, consequently, the SMD_{max} given by

$$SMD_{\max} = \frac{STD_c}{(k-1)} \quad .$$

We now have finally all the elements to estimate the Scaled Relative Asymmetry of axial line i (SRA_i) given by equation (22).

Scaling by this procedure assumes that the obtained form of depth distribution for axial line i is the same as the original one would be on a scale of equal units.

As the diamond shape has a distribution of depths from its root with mean depth MD_k (equation 12) and standard deviation given by σD_k (equation 20), this enables the scaling of RA by the results given in equation (22) which, in turn takes into account not just the values of mean depths, but also the variability of their distributions in axial maps.

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Mário Krüger (kruger@ci.uc.pt), is full Professor at the University of Coimbra, was a member of the Centre for Land Use and Built Form Studies at the University of Cambridge, which in 1978 awarded him a PhD in the area of architectural and urban morphology. He supervised more than six dozens master's theses and/or doctoral degrees at the Universities of Brasília, University College London, Cambridge, Technical University of Lisbon and Coimbra. With three books in the field of architectural theory and seven dozens of papers published in national and international journals, he produced, as co-author, a critical edition in Portuguese of the treatise De re aedificatoria by Leon Battista Alberti, published in 2011.

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5. Conclusions

The first section of the paper is a partial review of Krüger's original paper (1989), presenting some space syntax measures which are used in this study.

The results obtained in this paper are the outcomes of a study that took the standard deviation of the depth from an axial map into account. Introducing a new measure for axial analyses, the Scaled Relative Asymmetry of axial line *i* (SRA_i), suggests more powerful correlations with natural movement.

We propose that testing the correlation of SRA_i with natural urban movement will produce interesting results. These tests will be undertaken in a future study of the axial comparative analyses of urban maps representing Portuguese settlements, as well as Architecture Faculty buildings in Portugal. In the latter case, since two-dimensional plane axial maps do not apply to multi-storey buildings, the diamond shape should be mapped onto a sphere in order to take into account the genus of a three-dimensional surface, while novel derivations should be made for the mean depth and the standard deviation of these axial maps.

In short, although the derivation of the expression for RRA has been available since Krüger (1989), it is possible to work with a more robust statistical approach which not only takes into account its the mean depth values, but also the corresponding standard deviation for each axial line given by SRA_i. In other words, the proposition is to work not only with a measure of centrality, but also with a dispersion measure in order to obtain a more complete picture of the distribution of depth values in an axial map.

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